State Highway 9 Wildlife Mitigation Monitoring – Literature Review

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This literature review was prepared in conjunction with the State Highway 9 Wildlife Mitigation Monitoring Study, a joint research study supported by the Colorado Department of Transportation (CDOT) and Colorado Parks and Wildlife (CPW). The research team compiled and summarized recent published and gray literature on the current state of the science and practice of WVC mitigation and monitoring with a focus on ungulates in the western United States. The purpose of the literature review was to provide a comparative assessment of the best applications of different mitigation methods used to mitigate ungulate-vehicle collisions. The review emphasizes research conducted in Colorado and other Rocky Mountain states with direct applicability to Colorado's landscapes and wildlife populations. While much of this literature review was prepared in the first year of the study, additional recent published and gray literature were added to the review in the final year of the study.

The Literature review is presented in three sections, 1) Ungulate use of wildlife crossing structures, 2) Effectiveness of other wildlife-highway mitigation features, and 3) Mitigation project development and wildlife mitigation monitoring

UNGULATE USE OF WILDLIFE CROSSING STRUCTURES

Cramer, P. 2012. Determining wildlife use of wildlife crossing structures under different scenarios. Final Report to Utah Department of Transportation, Salt Lake City, UT. 181 pages. URL: http://www.udot.utah.gov/main/uconowner.gf?n=10315521671291686

This statewide study examined wildlife use of 14 designated wildlife crossing structures and 21 existing culverts and bridges built for other purposes. The author used motion-sensed cameras placed at structure entrances. Over three years (2008-2011) 35 cameras at the 35 structures recorded mule deer moving through or over the wildlife crossing structures 23,957 times, and the existing culverts and bridges 1,093 times. Passage rates were analyzed with respect to the dimensions of the bridges and culverts. Results indicated that the length of the structure was inversely related to success rate, i.e., the shorter the distance mule deer had to move under the highway, the greater the mule deer success rate. The author recommended that culverts be less than 120 feet long, but as the study continued, that length was extended to 140 feet as the maximum length recommended for a culvert to ensure mule deer success rates of over 75 percent. Culvert width was the second most important predictor of mule deer through-passage success, i.e., the wider the culvert, the greater the mule deer success rate.

Existing structures such as concrete box culverts for farm machinery and bridges for stream flow did not have as high success rates as dedicated wildlife crossings due, in part, to the lack of wildlife fencing to the structures in most cases, thus animals were not forced to use them. These other structures were also typically longer than 140 feet and were smaller in height and width overall than wildlife crossing culverts and bridges. Existing bridges in the study were all sufficient for allowing mule deer passage and could function as de facto wildlife crossings under I-70 and US 6, despite being constructed for other purposes.

During the study period there were over 24,000 mule deer movements through structures, but only 45 successful passages by elk, and 127 successful passages by moose. Elk did not use culverts to pass beneath the highways. A pair of traditional span bridges under I-70 had 12 successful passages by elk. All other bridges had only occasional elk use with single numbers of animals photographed at a time using them. North America's first wildlife overpass, on I-15, had a total of 19 bull elk successful passages, and was the most successful crossing structure in the study for elk.

The following wildlife crossing design recommendations were made:

- Mule deer will readily use culverts 120 feet or shorter to move beneath roads.
- To help ensure mule deer successful passage, culverts should be designed to be as short as possible, as wide as possible, and as tall as possible. Length is the most important factor, width the second, and height is the least important.
- All bridges designed for wildlife, specifically mule deer, had mule deer success rates from 89 to 98 percent. Bridges are the most successful underpass design for mule deer and other wildlife.
- Wildlife crossing structures should include 8-foot high wildlife exclusion fencing to guide animals to the structures.
- Double cattle guards or wildlife guards are needed at all ingress and egress points in the fence.
- Mule deer move day and night. In structures with low human use, mule deer used the structures 50% or more of the time in the daylight. The usefulness of wildlife crossings is diminished with human use.
- Elk did not use culverts. All crossing structures designed for elk herds, rather than occasional bulls, should be designed as bridges or overpasses.
- Stream crossing structures are excellent conduits for species diversity, and are areas where wildlife crossings, especially bridges, should be considered and built.
- Continued research of wildlife crossing structure designs and effectiveness is needed. Research is typically well under 2% of the cost of a project, and it helps verify whether the mitigation met its objectives, and adaptive management is needed.
- Continued collaboration and communication among state and federal agencies is needed for all wildlife mitigation, currently in existence and in the future. These dialogues help to identify areas of problems with wildlife and vehicle collisions, wildlife migration routes, maintenance fixes, and successes of wildlife mitigation.

Cramer, P., & R. Hamlin. 2019. U.S. Highway 89 Kanab-Paunsaugunt Wildlife Crossing and Existing Structures Research. Report No. UT-19.19. Report to Utah Department of Transportation, Salt Lake City, UT. URL: https://trid.trb.org/view/1659701

Cramer and Hamlin deployed Reconyx remote triggered cameras for about 5 years to study mule deer movements at three new and four existing wildlife crossing structures as well as wildlife exclusion fence ends and 2 cattle guards along a 12.5 mile stretch of U.S. Highway 89 within the Grand Staircase Escalante National Monument near Kanab, Utah. The project area crosses the seasonal migration path of the Paunsaugunt mule deer herd and, by the study's end, had an Annual Average Daily Traffic of 3,230 vehicles. Two new structures measure 15.5ft wide x 52ft long x 8.5ft high and one measures 18.6ft wide x 68ft long x 12ft high. The existing structures range in size from a 6ft wide x 84ft long x 7.5ft high culvert to a 55ft wide x 44ft long x 30ft high bridge. Researchers determined the effectiveness of each structure by calculating the total number of mule deer movements – categorized as success movements, repellency movements and parallel movements – and determining the success rate, rate of repellency and parallel rate for each structure and fence end. Researchers also investigated any relationships between mule deer success rates and structure dimensions and performed Before-After-Control-Impact analyses on Utah DOT crash data to determine any changes in crash rates.

Mule deer successfully used the seven structures 78,610 times (n = 102,517), with increasing success each year of the study. Mule deer moved through structures most months of the year, with increased success during seasonal migrations. The seven structures had an overall mule deer success rate of 77 percent by year five of the study. Six structures achieved individual mule deer success rates of over 90 percent, while one – the shortest, narrowest, and longest structure – achieved 70 percent, by year five of the study. Movements around the fence ends decreased throughout the study. Success rates were positively associated, though weakly, with larger structure height, width and openness ratios and negatively associated, again weakly, with structure length. Crash rates fell within the study area between pre- and post-construction, and these reductions were significantly different to comparable changes at control sites.

Relevance to Colorado:

- The dimensions and design (corrugated steel with natural bottoms) of the new culverts in this study are suitable for large numbers of migrating mule deer. They work well for jackrabbits and carnivores, but provide limited permeability for elk and pronghorn.
- Mule deer in the study area were able to adjust their movement patterns to within a mile of their former migration route.
- Increased structure height and width might improve the likelihood of mule deer successfully using a structure, while increased length might reduce it.
- Coordinating with appropriate agencies to install wildlife friendly fencing in areas with cattle grazing can improve mule deer success rates at structures.
- It took several years to see increased success rates at some structures, highlighting the importance of long-term monitoring.

Gagnon, J.W., N. L. Dodd, K. S. Ogren, and R. E. Schweinsburg. 2011. Factors associated with use of wildlife underpasses and importance of long-term monitoring. Journal of Wildlife Management, 75 (6):1477-1487.

The researchers used motion-triggered video camera surveillance systems to study wildlife use of 6 wildlife underpasses (connected by wildlife fencing) on a 27-km stretch of State Route 260 in central Arizona. Structure size ranged from 112-135’ span, 16-40’ height, 174-420’ length and 36-154’ atrium. Monitoring lasted for 2.5 to 5.5 years depending on the construction timeline for each individual structure. Through assessment of video footage, researchers determined the number of all species using each underpass, assessed rates of successful passage and, using multiple logistic regression, investigated the impact of a variety of structural and temporal factors on structure use by elk and white-tailed deer.

Researchers recorded over fifteen thousand visits by over twenty different species at the studied underpasses. Over 70% of these visits were successful passages. The majority of wildlife visiting the structures were elk. The average rate of successful passage for all species across all six structures was 0.58. Structure location and structure characteristics were determined to be the most important factors influencing successful use by elk and white-tailed deer. Most structures saw increased usage by elk over four years of study while only one did for deer.

Relevance to Colorado:

- Although biased against smaller animals, using video surveillance set-up offers a tested cost- and time-efficient method for post-construction wildlife monitoring.
- Continued importance of structural characteristics and location through four years of study suggest those factors are key to determining successful use by elk.
- Researchers found an increase in passage rate over time for elk at all structures, suggesting this species can take several years to habituate to new underpasses. Keen attention to design details can speed this adjustment period.
- When designing wildlife mitigation structures, eliminating vertical walls and ledges may improve use by ungulate species as these features may make them wary of potential predators. Maximizing visibility through the length of the structure and placing structures away from areas with continual human use may also maximize use.
- Researchers recommend wildlife mitigation features be placed on the landscape at a frequency that maximizes the opportunity of target species to come across and use structures.
- Researchers found that traffic volume did not affect elk crossings through structures under the roadway while additional papers of the researchers show effects on at-grade crossing probabilities.
- Differences in results in a 2.5-year study and this 4-year study in the same study area indicates the importance of long-term monitoring.

Sawyer, H., C. Lebeau, & T. Hart. 2012. Mitigating roadway impacts to migratory mule deer—a case study with underpasses and continuous fencing. *Wildlife Society Bulletin*, *36* (3):492-498.

Sawyer et al used Reconyx remote triggered cameras and an analysis of deer-vehicle-collision (DVC) rates to evaluate the effectiveness of 7 concrete box-culvert underpasses (approximately 20’ wide x 59’ long x 10-12’ high) and wildlife fencing installed on a 21-km section of U.S. 30

in southwest Wyoming. The study area is in sagebrush canyon habitat on a 2-lane highway through winter range and is an important migration route for mule deer. The majority of animals (83%) using the structures during the study were migrating. Equipment was deployed to cover mule deer spring and fall migrations and winter use over a 3-year period. From photos, researchers tallied the number of mule deer using each structure, cataloged the temporal patterns of mule deer use on a daily and seasonal basis, and determined rates of successful passage through each structure to assess the effectiveness of each individual structure and evaluate whether successful passage increased over time. Researchers also used DVC data to determine whether the mitigation effectively reduced DVCs in the study area.

Results show several thousand mule deer using the structures with a strong preference for two particular structures, including one that had been in place for several years. The other structures saw increased use over time. Deer use at most structures, including the preferred two, varied by season. Peak use occurred in the morning and evening, depending on season, and mid-December for fall migrations and mid-March and early May for spring migrations. Average successful passage rates at all structures increased to over 90% during the 3-year study. DVCs were reduced by 81 percent in the immediate vicinity. Several other species, including elk, pronghorn and moose, used the structures.

Relevance to Colorado:

- Study relevant to 2-lane highways through mule deer migration routes in Colorado.
- Preference of mule deer for two particular structures likely due to the proximity of those structures to an established migration routes. Thus, researchers recommend locating mitigation structures as close to established migration routes as possible, ideally determined with verified movement data.
- Researchers found an increase in passage rate over time, suggesting mule deer need several years to habituate to new underpasses.
- Researchers believe the underpass structures used in this project may be of value to other ungulate species, besides mule deer, as well.

- Researchers believe DVCs can be reduced even further (potentially to zero) through better management of gates and other infrastructure found along the fence.
- By reducing DVCs, cost analysis estimates the mitigation project is saving nearly $800,000 a year and the total project cost will be recouped in approximately 5 years.

Sawyer, H., & P. Rodgers. 2015. Pronghorn and mule deer use of underpasses and overpasses along U.S. Highway 191, Wyoming. Report No. FHWA-WY-06/01F. Report to Wyoming Department of Transportation, Laramie, WY and U.S. Department of Transportation Federal Highway Administration. URL: https://rosap.ntl.bts.gov/view/dot/34368

Sawyer and Rodgers used Reconyx digital infrared cameras over a 3-year period to study mule deer and pronghorn use of crossing structures along U.S. Highway 191 near Pinedale, WY. The 12-mile study area is on a two-lane highway through an important migration route characterized by sagebrush and riparian habitat and irrigated hay fields. The study area is divided into two sections – one running east-west, the other north-south – each with one overpass and three underpasses. The overpasses are 150'wide with 4' dirt berms on each side. The bridge underpasses measure about 66' wide x 43' long x 13' high. Wildlife exclusion fencing connects all structures. Structures were placed at wildlife-vehicle collision (WVC) hot spots and intersections with migration routes, including Trapper's Point, a known bottleneck. The traffic volume before construction was around 2,000 vehicles/day with an annual average of 85 WVCs (mostly mule deer). Researchers catalogued each complete movement over or through a structure, analyzing the data for the entire study area and the two sections separately to determine structure preference and daily temporal trends during seasonal migrations. Researchers also assessed movements opposite the direction of migration (non-directional) and compared pre- and post-construction Wyoming DOT WVC data.

Mule deer used the structures most during spring migration (*n*=22,216), followed by winter (*n*=19,130), fall migration (*n*=18,033), and summer (*n*=608). Seventy-nine percent of mule deer crossed under the highway, showing preference for one particular structure in each section. Pronghorn used the structures most during fall migration (n=10,219), followed by winter (n=4,084), spring migration (n=3,071) and summer (n=1,882). Ninety percent of pronghorn preferred to cross over the highway, with 80 percent of movements occurring at the Trapper's Point Overpass. Mule deer moved more in the morning and evening while pronghorn moved throughout the day. For both species, non-directional movements during migration increased between year 1 and 2, stabilizing thereafter. WVCs involving mule deer decreased by 79 percent and pronghorn WVCs fell to zero. Ten other species were also documented.

Relevance to Colorado:

- Migrating pronghorn showed a strong preference for overpasses, while mule deer preferred the less expensive underpasses, in this open sagebrush habitat.
- Increased non-directional movements may indicate the structures provide flexibility to respond to environmental cues affecting seasonal migrations, improved access to habitats, and additional breeding options.
- Coordinating with appropriate entities to deter human use (i.e. hunting, ATVs) and maintain wildlife friendly cattle fencing at structures can support use by target species.
- Maintaining cattle guards and gates along wildlife exclusion fencing is important for further reducing WVCs.

Simpson, N.O., K.M. Stewart, C. Schroeder, M. Cox, K. Huebner, and T. Wasley. 2016. Overpasses and underpasses: effectiveness of crossing structures for migratory ungulates. Journal of Wildlife Management. DOI: 10.1002/jw.21132.

Nevada DOT constructed two overpasses and three underpasses on US Highway 93 (US 93) in northeastern Nevada in 2010 and 2011. The researchers monitored mule deer use of these structures with Reconyx brand professional cameras from September 2010 to May 2014. They documented mule deer successfully using the structures 35,369 times over eight migratory periods. They documented three elk approaching the underpasses, with just one successful crossing movement. They also documented three elk approaching and successfully crossing over the overpass. Pronghorn antelope also used the overpasses. The mule deer success rate at the overpasses was greater than 94 percent. Mule deer success rate at the underpasses was low and increased each year, but it remained at 60 percent the final migration monitored. Using generalized linear models, the authors found an effect of site, structure and interaction between study site and structure. The major finding of this study is that they found mule deer preferred using the overpasses over underpasses. With two study areas, both having an overpass and one or two underpasses, the study supports the hypothesis that mule deer prefer overpasses to underpasses. The overpass at 10-Mile Summit was wider and shorter than the overpass at HD Summit, and had higher number of mule deer using it. The underpasses were cylindrical corrugated metal culverts six meters (18 feet) high, therefore their results could only be applied to this type of underpass. The authors stressed that both types of wildlife crossings studied are important tools for restoring connectivity of landscape and reducing deer-vehicle collisions.

van der Grift, E. A., R. van der Ree, L. Fahrig, S. Findlay, J. Houlahan, J. A. G. Jaeger, N. Klar, L. F. Madrinan, and L. Olson. 2013. Evaluating the effectiveness of road mitigation measures. Biodiversity Conservation 22:425-448.

The authors outline guidelines for research methodologies to effectively evaluate wildlife mitigation features beyond simply assessing wildlife use at a given structure. The first step is to determine the focal species and outline objectives of a given mitigation project such as improved human safety, benefits to the wellbeing of wildlife or wildlife conservation concerns and determining the amount of remaining road effects will be acceptable post-mitigation. Clear objectives that are “Specific, Measureable, Achievable, Realistic and Time-framed” (SMART) (Doran 1981) should be defined from the beginning. The second step is to determine the target species to study whether all species will benefit from mitigation or a carefully selected subset. Authors outline several considerations to help with the latter. The third step is to compile “measurement endpoints” to determine the effectiveness of road mitigation efforts based on the mitigation objectives (human safety, wellbeing of wildlife, conservation concerns). Authors describe several endpoints for each goal type such as total number of human fatalities or injuries as a consideration when assessing improved human safety. The fourth step is to choose a study design that will provide reliable and useful results, ideally one that includes control sites and pre- and post-construction data collection (i.e. Before-After-Control-Impact). The authors outline additional options that might be appropriate depending on the circumstances of a given situation.

The fifth step is to select an appropriate sampling scheme and determine design variables such as length of study, monitoring frequency and the necessary number of replications, the answer to which will be tied to the measurement endpoints and target species. The authors suggest using model-based power analysis to help ensure adequate statistical power for any given design variable. The sixth step is to choose the location and size of mitigation and control sites to study and authors outline several considerations to help with this determination. The seventh step is to determine additional covariates to study, such as road design and local landscape features, to strengthen the interpretation and understanding of results. The eighth step is to determine appropriate survey methods, such as using remote-triggered cameras, road surveys, or genetic sampling, for a given measurement endpoint, target species and study design. The ninth and final step is to determine the needed resources, financial and otherwise, to understand the viability of a given monitoring plan. The authors conclude the paper with an appeal for collaboration between researchers and road practitioners to begin as early as possible and for funding and other resources be secured prior to construction of road mitigation projects to ensure the strongest evaluation possible.

Relevance to Colorado:

- The paper outlines guidelines for researchers to follow to improve effectiveness monitoring of road-wildlife mitigation efforts.
- Authors reiterate the importance of long-term monitoring to ensure accurate results can be gathered.
- Guidelines help increase the scientific rigor of transportation and wildlife studies, allowing for statistical analyses to help researchers make stronger recommendations for future mitigation and adaptive management.

Literature Cited:

Doran, G.T. 1981. There is a S.M.A.R.T. way to write management goals and objective. Management Review, 70(11):35-36.

EFFECTIVENESS OF OTHER WILDLIFE-HIGHWAY MITIGATION FEATURES

Cramer, P. and J. Flower. 2017. Testing New Technology to Restrict Wildlife Access to Highways: Phase 1. Final Report to Utah Department of Transportation. Report No. UT-17.15. 70 pages. URL: http://www.udot.utah.gov/main/uconowner.gf?n=37026229956376505.

This study looked at five existing types of wildlife barriers at fence openings along highways, and how well electric pavement may prevent mule deer from entering highways at access points. The two-part study first looked at existing barriers, then placed electric pavement in front of single cattle guards to test effectiveness. The researchers placed Reconyx brand professional cameras at 14 wildlife deterrent barriers: two single cattle guards without excavation pits, four single cattle guard over excavation pits, four double cattle guards over excavation pits, two wildlife guards (grid pattern double cattle guards) over excavation pits, and two electrified mats embedded in the road (Electromat brand).

Cameras captured 1,946 individual mule deer movements near the barriers. The study found double cattle guards deterred 94 percent of all individual mule deer movements (n=783). Wildlife guards deterred, on average, 87% of all individual mule deer movements (n=339). The other wildlife deterrent barriers were less effective in deterring mule deer movements – single cattle guards with excavation pits averaged 53 percent effective (n=139), single cattle guards with no pits averaged 28 percent effective (n=403), and electric mats averaged 11 percent effective (n=161). Generalized linear models found that the wildlife barrier type was the most important predictor of whether a mule deer crossed over them. Researchers recommended the use of double cattle guards and wildlife guards to deter mule deer from entering highways at break points in fencing.

In the second part of the study, the researchers placed electric pavement in front of single cattle guards at baited wildlife exclosures in the wild and at a single cattle guard embedded in a road leading to an exit on Interstate 15 (I-15). Single cattle guards augmented with electric pavement in the front leading edge were 91 percent effective in deterring individual mule deer from entering feed baited exclosures in the wild. Electric pavement placed in the road at an I-15 interchange was 64 percent effective in deterring 31 individual mule deer approaches. In the second phase of this study (Cramer and Hamlin 2017), the electric pavement and single cattle guard were found to be 46 to 50 percent effective in deterring individual mule deer from entering the road (n=47).

Relevance to Colorado:

- The researchers recommend that UDOT and other DOTs continue using double cattle guards and wildlife guards while electric pavement is further developed and tested, using wider pavement designs and other alterations.

Literature Cited:

Cramer, P. and R. Hamlin. 2017. Testing new technology to restrict wildlife access to highways: Phase 2. Report to Utah Department of Transportation Report No. UT-17.16. 35 pages. URL: http://www.udot.utah.gov/main/uconowner.gf?n=37026118257278521.

Siemers, J.L., K.R. Wilson, & S. Baruch-Mordo. 2015. Monitoring wildlife-vehicle collisions: analysis and cost-benefit of escape ramps for deer and elk on US Highway 550. Report No. CDOT-2015-05. Report to Colorado Department of Transportation, Denver, CO.

https://www.codot.gov/programs/research/pdfs/2015-research-reports/wildliferamps

Siemers et al used Cuddeback motion-triggered cameras to study 11 escape ramps (ER) and 2 escape jumps ("intentional gaps in the fencing above [a] box culvert headwall") on an eight-mile stretch of U.S. 550 in southwest Colorado that is fenced entirely with 8-foot wildlife fencing. The study area elevation is approximately 6,500-7,000 feet with rolling pinon-juniper and mountain shrub habitat mixed with riparian areas and agriculture. The area has several resident mule deer herds. There are no wildlife crossing structures in this section of roadway. Of the eight ERs detailed, slope varied between 2:1 and 3:1 and height varied between 6 feet, 6.5 feet and 4.5

feet high with rail fence. The study lasted for two years. Two cameras were deployed at each ER and set to take a photograph and a video with each trigger which were then analyzed to tally the number of successful and unsuccessful escapes and reversals (animals jumping from the habitat to the right-of-way side of the ER). One camera was also deployed at each of 2 escape jumps in the study area. Logistical regression, Poisson regression and quasi-Poisson were used to evaluate the data.

Researchers were able to determine escape success for 2,588 of the nearly 3,000 mule deer visits to ERs in the study area. Over half of the mule deer approaches on top of the ramps resulted in a successful escape. An ER located near a state park entrance had the most deer visits; successful escapes and 25 of 27 successful reversals, where an animal used the ramp to enter into the fenced right-of-way. Morning and evening, as well as fall and spring, saw the most mule deer visits. Of the design and landscape features analyzed, presence of guide fencing were correlated with successful escape attempts while bar presence and a farther distance of the ER to the highway and the nearest shrub were correlated with unsuccessful escape attempts by mule deer. The importance of the proximity of the nearest tree varied by analysis. A small sample size and other considerations confounded the results. The outcome of 49 of 52 elk visits to the top of ramps were also confirmed, with a little over half deemed successful escapes and no reversals. Most visits by elk occurred during the spring and summer and at the escape ramp situated the greatest distance from the highway. The two escape jumps saw divergent degrees of use, one with only 22 deer visits and 3 successful escapes, the other with 147 deer visits, 42 successful escapes and 4 reversals. Escape success rates for mule deer ranged from 8.2% to 70.3% across the 11 escape ramps.

Relevance to Colorado:

- Cost-benefit analysis found that by reducing WVCs, the total project cost was recovered in 1.35-2.2 years (depending on the cost estimates used).
- Researchers found that mule deer were more likely to make a successful escape at ramps with guide fencing, close to the highway, and with shrubs in close proximity (but not in the landing area).

- Researchers recommend leaving 16-32’ on the habitat side of an ER clear of vegetation.
- Based on the seasonality of deer visits, seasonal signage warning drivers of deer presence is recommended during periods of high deer activity.
- Researchers believe WVCs can be reduced even further through better management of infrastructure and give various specific recommendations for improvement.

MITIGATION PROJECT DEVELOPMENT & WILDLIFE MITIGATION MONITORING

Kintsch, J. P. Basting, M. McClure, & J.O. Clarke. 2019. Western Slope Wildlife Prioritization Study. Report No. CDOT-2019-01. Report to Colorado Department of Transportation, Denver, CO. URL: https://www.codot.gov/programs/research/pdfs/2019/WSWPS/wswps_final_report_april_2019-revised-5-3-2019-copy.pdf

The Western Slope Wildlife Prioritization Study (WSWPS) emerged from a commitment to increased collaboration between Colorado Department of Transportation (CDOT) and Colorado Parks and Wildlife (CPW) to address wildlife conflicts on roads. The study’s objective involved identifying wildlife-highway conflict areas where targeted mitigation could have the greatest impact on reducing WVCs. To meet this objective, the WSWPS identified, mapped and prioritized highway segments across the West Slope based on the risk of WVC and the need for mule deer and elk to make cross-highway movements, particularly during migration or within winter range. The prioritization results and mitigation recommendations for the top 5-percent priority segments in each region were then integrated into a decision-support framework. In addition to the prioritized highway segments and preliminary mitigation recommendations, the decision-support framework includes a benefit-cost analysis tool, an implementation considerations matrix, and guidance for integrating mitigation for priority segments into CDOT transportation planning and project development.

This study's results will inform the siting, design, and construction of effective wildlife-highway mitigation projects across the Western Slope. This report includes a decision-support framework and tools to guide mitigation implementation in the highest priority highway segments. In addition, several recommendations are provided as next steps for CDOT and CPW to advance the outcomes of this research.

Rytwinski, T., R. van der Ree, G. M. Cunnington, L. Fahrig, C. S. Findlay, J. Houlahan, J. A. G. Jaeger, K. Soanes, and E. A. van der Grift. 2015 Experimental study designs to improve the evaluation of road mitigation measures for wildlife. Journal of Environmental Management 154:48-64. DOI: 10.1016/j.jenvman.2015.01.048

This paper outlines a research approach intended to rigorously evaluate the effectiveness of wildlife mitigation features. The authors identify a series of seven questions, the answers to which they state are necessary for road planners to make informed decisions on roadway mitigation for wildlife and get the best results for population viability of target species. The questions are as follows:

1) Does a given crossing structure work? What type and size (width, height and length) of crossing structures should we use?
2) How many crossing structures should we build? i.e. how far apart should crossing structures be?
3) Is it more effective to install a small number of large-sized crossing structures or a large number of small-sized crossing structures?
4) How much barrier fencing is needed for a given length of road?
5) Do we need funnel fencing to lead animals to crossing structures, and how long does such fencing have to be?
6) How should we manage/manipulate the environment in the area around the crossing structures and fencing?
7) Where should we place crossing structures and barrier fencing?

The authors walk through each identified question, outlining potential experimental study designs, defining strategic time frames for research development and implementation (i.e. pre-construction/planning or post-construction stages of road construction/improvement projects) and highlighting example case studies. The authors note that implementing a rigorous experimental design is not necessarily easy. Issues might include concerns with potentially implementing less effective mitigation measures in the name of research, dealing with ideal versus realistic time frames, and persuading transportation authorities that experimentation is necessary and within their realm of responsibility. The authors offer some potential solutions to some of these issues as well as for circumstances when experimentation is not possible.

Relevance to Colorado:

- The authors tout an experimental approach - ideally including collection of pre-construction population data and a Before-After-Control-Impact (BACI) study design with replication and randomization - to gain stronger inference and provide new knowledge that can be applied to future mitigation projects.
- The authors promote researcher involvement as early as possible in a transportation infrastructure project (i.e. at the strategic planning stage) in order to allow for greater flexibility in the experimental study design (i.e. number, type and locations of treatment and control sites) and more time for pre-construction monitoring.

Roedenbeck IA, Fahrig L, Findlay CS, Houlahan JE, Jaeger JAG, Klar N, Kramer-Schadt S, van der Grift EA. 2007. The Rauischholzhausen agenda for road ecology. Ecology and Society 12(1):11. URL: http://www.ecologyandsociety.org/vol12/iss1/art11/

This paper is the result of the authors meeting in Germany and trying to find ways transportation ecology could have greater influence on transportation decision making. The authors wanted to help define the relevant questions and methods to answer those questions.

Relevance to Colorado:

- Manipulative experiments, where the researchers and managers are setting up specific studies that are replicated, maximize inferential strength, but real-world constraints may restrict the ability to design such research studies.
- The authors strongly recommend a BACI method of research – Before-After-Control-Impact. The paper helps explain how researchers could conduct a before-after designed study if a control in not available, or a control-impact study if pre-intervention (impact) data collection is not available. The best studies however, combined both a pre and post construction period, all the while monitoring a control area during the entire length of the study.
- When dealing with the natural world, it is important to extend a study over time and space, because of changes in weather and climatic events like flooding and fire, and changes in wildlife population numbers and distribution. This helps the statistical analyses to be more robust and allows greater strength in inferences as to changes in wildlife-vehicle collisions over time, and wildlife use or lack of use of structures.